Fermilab

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REFRIGERATOR PROCESS CONTROL SYSTEM FOR THE SSC

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Introduction

On January 17-19, 1984 a workshop on cryogenics for the SSC was held at Brookhaven National Laboratory. I participated in a group which discussed controls, instrumentation, and simulation methods and philosophies for cryogenic applications.

We had approximately one day to discuss these three topics and each person's experiences, prejudices, and recommendations. The discussions were interesting and enlightening but we did not have time to come to many firm conclusions and recommendations. The subject of control systems was one that was especially difficult to make progress on in a short time.

Our group made some general recommendations on the direction that future work should take and this report contains my specific opinions on instrumentation and control of cryogenic systems. These recommendations are based on discussions within and outside of our group and my own experience building and operating the Fermilab Cryogenic Process Control System.

Instrumentation Temperature Monitors

Carbon and platinum resistors and semiconductor diodes should be used for temperature measurement. They are reliable, inexpensive, and easy to install (with backup devices) on large scale systems. One disadvantage of these devices is that carbon resistors and diodes require individual calibration curves. I believe that this is offset by the fact that they can then be used over wide temperature ranges. Another distinct advantage is they can be easily tested in place to confirm proper operation. Research into devices that have better linearity and unit-to-unit repeatability over wider temperature ranges should be started immediately.

Vapor Pressure Thermometers (VPT's) on the other hand have proved very difficult on large scale applications.

Installation of the bulb and capillary tubing without leaks or plugs in the system for hundreds of devices is tough!

Proper pumping, purging, and charging of VPT's for low temperature measurements is especially labor intensive with no assurance of proper operation until cooldown of the system has occurred. When improper operation occurs it is very difficult to determine whether the cause is a faulty VPT or transducer, and repairs require either system warm-up or cold charging of the VPT.

Pressure Transducers

Refrigerator designers should provide specifications required for these devices early in the design process. Instrumentation engineers need to know specifications unique to cryogenic accelerator applications. A partial list of these specifications and/or questions are:

1. Normal operating pressure and resolution desired.
2. Peak and time dependent overpressures that may be encountered during quenches or decontamination.

3. Unique operating environments.
   a. Will liquid air sometimes drip on transducer?
   b. Will water drip on the transducer?
   c. Can the transducer be frozen during decontamination cycles due to flow direction changes?
4. Must the transducer be vacuum and/or pressure leak tight?
5. Should it operate in a vacuum?
6. Will any mechanical, electrical, or digital filtering be required to reduce pressure oscillations caused by normal operation of rotating machinery or other subsystems?
7. Are gauge pressure transducers sufficient or are absolute pressure transducers necessary?
8. Will the measurement be made in or near a radiation area?

These parameters directly affect the cost and reliability of the system and should not be overlooked.

Valve Actuators

Remote indication of actual valve position, which confirms proper operation of the actuator-valve assembly has proven to be most useful at Fermilab and should be used in the SSC. Many actuators will be located on components in the tunnel where normal access is limited to infrequent maintenance periods.

The type of actuator that is used for operating the valves is not as critical but must be specified properly to obtain the desired result.

Some of the questions that should be answered are:

1. Electric or pneumatic? If pneumatic, is there a clean, dry, low maintenance source of operating gas available.
2. Can the number of different actuators be minimized to simplify procurement, installation, and maintenance procedures?
3. Specify the direction and magnitude of operating forces for both normal and extreme cases.
4. How accurately must the valve be positioned?
5. What is the smallest adjustment in position that must be made?
6. Does the actuator need to fail open, closed, or hold position?
7. What is the stroke length or rotational angle of the valve?
8. Should the stroke or angle be mechanically limited to prevent valve damage?
9. What seating forces are required to properly seal the valve?

These questions may seem obvious to many designers but they tend to be overlooked when many engineers are working on different phases of a large project.

The Control System

This subject has a large diversity of opinion. I will try to explain my opinion, based on experience with the Fermilab system and discussions with persons from other labs.

Each refrigeration station should have a complete, stand-alone computer process control system. Each system should be linked to the Main Control Room of the SSC and be completely operable from that location. It may be desirable, though not mandatory, to have a to have a separate communications link for the cryogenic system. A block diagram of this system is shown in Fig. 1.

Completely operable from a remote location is defined as follows. Once the system is decontaminated the refrigerator should be able to be automatically or semi-automatically cooled down from room temperature to an operating condition, ready for beam, from the Main Control Room. After reaching this condition, operation should be fully automatic.

A console for local control may also be desirable or mandatory because of the large distances involved.

Crosstalk on the datalink between refrigerators may also be necessary and should not be ruled out. This data exchange should not become so complicated that an individual system is no longer stand-alone if the link fails. Simply put, failure of one part should not jeopardize the whole.

Data logging of parameters should be done on a local level to prevent a global loss of information in event of a link or Host computer failure.

Data logging may indeed be mandatory on a local level because of long time constants in a large system. Control loops may need logged data to make intelligent decisions on how much and which direction to move a valve. It would also be quite useful to know the past history of how a refrigerator reached a certain operating condition.

There will most likely be approximately 400 or more analog channels of data for each refrigerator. With 12 refrigerators this results in more than 5000 channels being logged at any one time, not including time and date stamps. I believe it would be desirable to only transfer this information to the Host when requested, to prevent excess link traffic.

Commercial process control systems should be thoroughly investigated for this use. There are systems on the market (Brookhaven has several) that provide all the described functions in one package. They provide process loop control, data logging, interlock sequencing, state switching for cooldown sequencing, and all the other functions and I/O normally associated with a process control system.

These systems have their own operating system with a process control language that can be programmed by the system engineer. This then frees the professional programmers to do the more complicated tasks at the Host level.

Conclusions

The development of these instrumentation and control concepts, as well as new ideas, should begin during construction and testing of prototype magnets and refrigerators. This will help insure that a system is built which satisfies its users and provides the information, control, and reliability necessary for such a large accelerator system to function.

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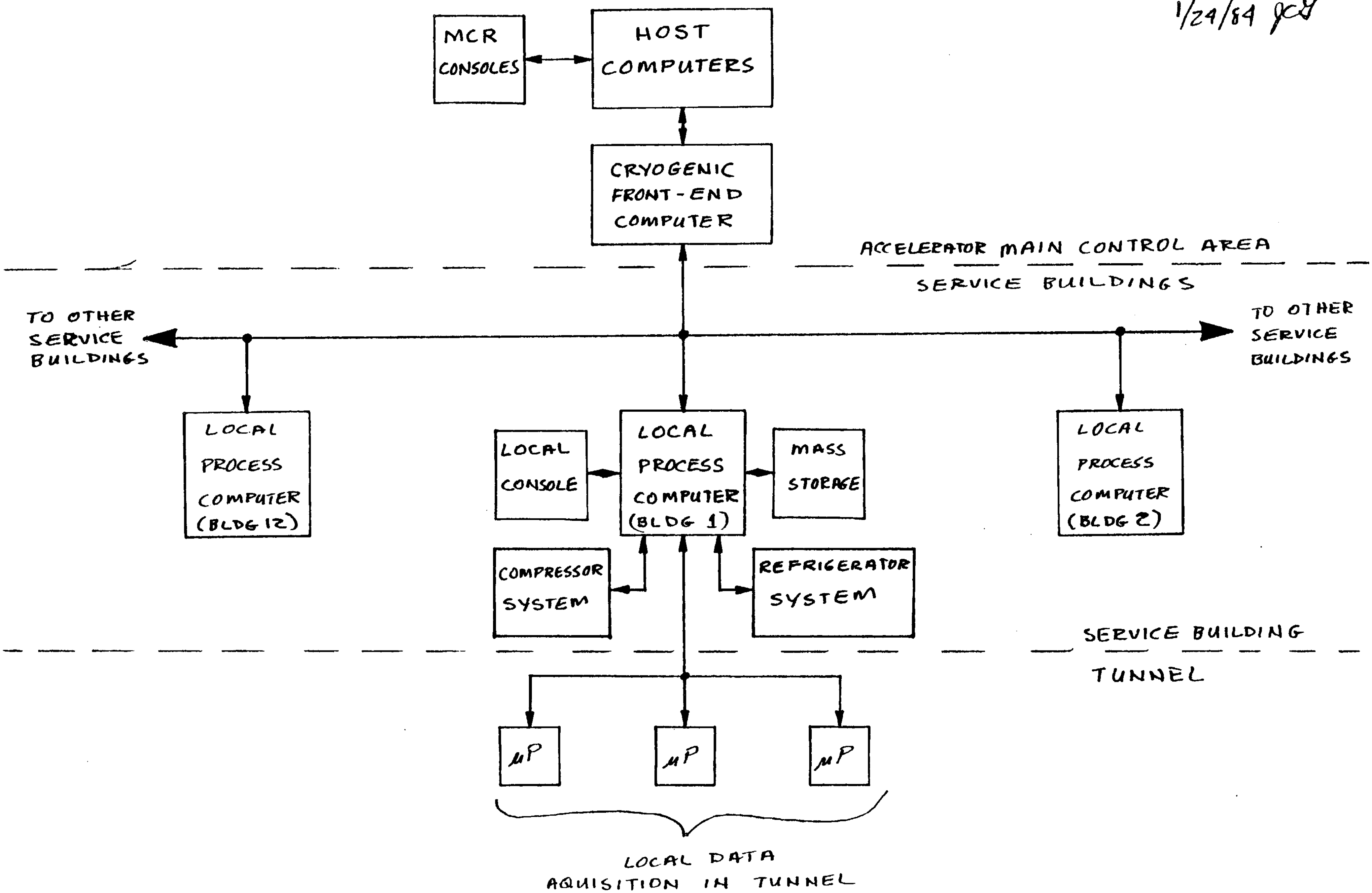

FIGURE - POSSIBLE CRYOGENIC CONTROL SYSTEM FOR THE SSC